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An Overview of Drought Hazards and Prospective Mitigation Approach in Bangladesh

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Authors' contributions

This work was carried out in collaboration between all authors. Author MAR designed the study, wrote the protocol, and wrote the first draft of the manuscript. Authors MSA, ME, MA and MBH managed the literature searches and took part in the analysis and author MAR prepared the final version of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Drought is the most formidable disaster frequently reoccurring in most regions of Bangladesh. It is a natural slow onset hazard which evolves unnoticed and enhancing due to the onslaught of global climate change. It is characterized with the long periods of dryness and shortage of water supply cumulatively impacting adversely on the socioeconomic development of the people and their properties. It is also defined as atmospheric / meteorological, hydrological and agricultural conditions which are closely related, in which meteorological is the source of the rest. Long term instability of temperature and rainfall pattern leads to local and regional drought hazards which impact productive sector failure and worsen socio-economic status. Agricultural activities which are

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the foundations of the socioeconomic aspect of Bangladesh suffer the impacts of drought most. It is due to the absence of solid understanding of the causes of drought in Bangladesh, the impacts of drought on the agriculture and socioeconomic life of Bangladesh, and the available of opportunities which could have been exploited to obtain mitigation of the adverse impacts of drought in Bangladesh and in similar conditions elsewhere. This study dwelt on the causes and impacts of drought on the agriculture and socioeconomic life of Bangladesh, and the opportunities which could be exploited to obtain their most effective mitigation and adaptation to. Aim is to minimize the impact of drought for enhanced sustainability of growth in the agricultural sector and socioeconomic life of Bangladesh and other countries in similar conditions.

Keywords: Drought hazards; temperature and rainfall; agricultural activities; social crisis; mitigation measure and sustainable development.

1. INTRODUCTION

1.1 The Natural Disasters of Bangladesh

Every year Bangladesh experiences different natural disasters like the incidence of flooding, drought, cyclones, river bank erosions, earthquakes, etc. [1]. But, drought is the most formidable disaster frequently reoccurring in most regions of Bangladesh. It is a natural slow onset hazard which evolves unnoticed and characterized with the long periods of dryness and shortage of water supply cumulatively impacting on life and properties. It refers to the water shortage problem in different sectors like as domestic uses, agricultural and industrial purposes. Drought can also be defined as atmospheric/ meteorological, hydrological and agricultural conditions which are closely related, in which meteorological is the source of the rest.

1.2 Drought Impacts

Droughts are directly or indirectly responsible for the reoccurrence of social crises like malnutrition, famine, conflicts, etc. They also influence on the distribution and density of populations as people won't settle in the areas experiencing shortage of life supports like rainfall and water [2].

Climate change enhanced droughts and the floods which follow adversely impacts on the agricultural sector. In accordance to the IPCC special report on climate change and its probable effects on rainfall pattern and warmer climate in Bangladesh [3], the country may experience a 5-6% increase of rainfall by 2050 owing to the increase of snow melting attributed to more intense monsoon which is accompanied with prolonged periods of heavy flooding and followed by increased monsoon drought.

Moreover, vast areas of South Asia including central Pakistan, southern Pakistan, and western India are also severely drought affected from early 2000 onward and categorized as one perennially drought-prone regions of the world. In the past five decades, Sri Lanka, Pakistan, India and Afghanistan experienced at least one year of drought in the periods of every three years. Like in Bangladesh, drought is also frequently reoccurring in Nepal [4].

Of the most recent 19 drought events experienced in Bangladesh, the 1973, 1978, 1979, 1981, 1982, 1992, 1994, 1995, 2000 and 2006 were the most severe [5]. From 1949-1991, almost 24 drought events occurred in Bangladesh, including the 1984, 1982, 1981, 1975, 1972, 1961, 1958, 1957 and 1951 most severe which inflicted long term cumulative impacts on 53% of the population and 47% of area [6]. Bangladesh also had foremost experiences on some high magnitude drought in 1995, 1994, 1992, 1989, 1982, 1981, 1979, 1978 and 1973 [6,7], as different of regions of Africa, Asia, Europe, America and Australia got their longer experiences of intense drought hazards from 1950 [8].

The climate change caused global warming and the resultant increase of its temperature also causes rise of sea level rise due to the rise and other disasters which also impact on crops. The cyclone mostly affecting the coastal region is one of these other disasters [9].

In general, Bangladesh is one of the most vulnerable countries to climate change that is the long term variation of climatic parameters-temperature, precipitation, humidity, wind direction and pressure, and it's enhancing of natural flooding, drought and cyclone disasters. It is the country which experiences the highest frequency of droughts in a year. The mean temperatures recorded in Bangladesh ranges from 26.9 to 31.1℃ during summer and 17 to 20.6℃ during winter. In the climatic point of

view, drought in Bangladesh can be categorized into three distinct types: (i) the winter season- from November to February; (ii) the pre-monsoon hot summer season from March to May; (iii) and the rainy season -from June to October [10]. Drought and its severity have also some social insecurity.

1.3 Mitigation

The scientific concern on the changing pattern of precipitation in Bangladesh includes the understanding of most important factors which influence for consideration in the determination and/or implementation of mitigation to reduce its drought impacts via risk and vulnerability assessments [11].

The Bangladesh of today is characterized with a high population growth and food demands the existing trends in crop production in the country won't satisfy. Farm productivity is decreasing due to the long term effects of climate change and its severity which might impact colossal damage of local and regional dimensions.

1.4 General Characteristics of Drought in Bangladesh

Every year reoccurrence of drought hazards is a common phenomenon in the Northern part of Bangladesh where it negatively impacts on the social and food securities, and the overall socioeconomic growth of the affected area. Several papers have reported on the impacts of droughts on land degradation [12-14], food production [15,16], agriculture [17-21], society [16,22] and economy [16,23].

Change of land use is one of the main causes of reoccurrences of drought hazards which are more frequent in Bangladesh than in its neighboring countries [24]. The sustainability of foods generation from agriculture in accordance to the needs of local communities and the country as a whole is hampered by the incidence of frequent and severe drought. Rahman and Biswas [25] reported that, crop production in the country decreased by 60-70% due to drought. Paul [26] also reported that, most of the households (e.g. who are belonging to lower socio-economic group) in the northern part of Bangladesh are severely drought affected. In 1982, 52,896 metric tons rice production was lost due to drought hazards [27] while 41% of the total loss was caused by different types of environmental crisis. In 1978-1979, it is estimated there was a drop of 2 million tons of rice production due to drought [28] which affected 44% of the population and 42% of the land cultivated directly [16]. The drought events also impacted adversely on water supply and demand. As a consequence, the incidence of drought impacts very negatively on the regional economic growth in the northern districts of Bangladesh and the country as a whole.

This study dwells on the causes and impacts of drought on the socioeconomic life of Bangladesh and the opportunities which could be exploited to obtain their most effective mitigation.

2. CAUSES AND IMPACTS OF DROUGHT HAZARD IN BANGLADESH

Bangladesh is located between 20°34' and 26°38' north latitude and 88°01' and 92°41' east Longitude. In terms of climatology, Bangladesh is positioned at the sub-tropical region. Mean precipitation in the country varies from 1,329 mm in the northwest to 4,338 mm in the northeast [29]. The average rainfall in the western part is approximately 2,044 mm; much lower than in others parts of the country [11].

Disasters, natural hazards and risks in Bangladesh are mostly considered geographical in nature [30,31]. Every year drought is experienced in some parts of the country, but mostly in the northwestern part which includes Rangpur and Rajshahi divisions.

Bangladesh also experiences frequent seasonal and contingent droughts, but doesn't have any permanent drought-prone area. It is a densely populated agro-economy based country with high and low levels of poverty and economic growth respectively. Weather is predominantly reverse monsoon, but also influenced by some other factors. Temperature is gradually rising, and therefore causing regional hazards like water shortage, soil drying, monsoon rainfall variability and enhanced evaporation.

The Himalayan Mountain is situated in the north of Bangladesh. As a result, heavy rainfall is received during the monsoon. In some of the rainy seasons it receives a lot of waters which cause flooding on the low lying areas mountain areas. If climate change was happening in a regular pattern it would inflict flooding hazards beyond water holding capacities on both high and low lands [32].

The causes of drought are closely related to the climatic variability which is inversely related to the decreasing blanket of vegetation cover on Earth's surface. Continuing change of climate variables may cause drought hazard. Most of the rivers could end drying-up due to the long term impacts of rainfall uncertainty and artificial barrage in the up-streams.

In addition, the South Asian least develop countries (LDCs) always experience all types of high frequency drought hazards like meteorological, agricultural, socio-economic and hydrological. These countries are facing some threats of rainfall uncertainty which include inter-regionally, intra-annually and intra seasonally. Nevertheless, monsoon rainfalls sometimes delay for 20 to 30 days, adversely impacting on crops and livelihoods [33]. These countries have are similarly poor and affected by drought, population growth and most vulnerabilities [34,35].

Decreasing river flows in the dry season is negatively impacting on the ecosystem, river morphology and aquatic ecosystem in the western part of Bangladesh [11]. In the country, Brahmaputra River is the most vulnerable to the decreasing flows in the dry season, where a 26 million population is subjected to food insecurity [36]. On the other hand, Ganges-Brahmaputra river basin is considered susceptible in the times of monsoon rainfall and extreme flooding [37, 38]. Water in the Ganges River has decreased significantly by approximately 57% downstream beyond Farakka Barrage [39]. Teesta is the main river in the northern part of Bangladesh. It enters Bangladesh through the Nilpharmary and Lalmonirhat Districts. The Government of Bangladesh has constructed a barrage on Teesta River at Dalia in Lalmonirhat district, which is a major source of water for irrigation in the northern part of Bangladesh. Its neighbor India has also constructed an embankment on Teesta River within its territory at Gazoldoba in Jolpaiguri [40,41]. During the monsoon season, all doors of Gazoldoba barrage in India are opened causing flooding in the lowland areas of the northern part of Bangladesh. On the other hand, during dry season only few doors are opened, causing drought. Afroz and Rahman [42] reported that the Teesta and Farakka barrages have reduced water flow by 80%.

Meteorological drought is an indication of unstable condition of climatic parameters such as rainfall uncertainty, temperature variation, high evaporation rate, lower humidity, cloud formation uncertainty and the dryness condition of the atmospheric environment [43]. It brings hydrological and agricultural drought [Figs. 1(c), 1(d)].

The times hazardous droughts are characterized with low rates of river discharge and the over extraction of groundwater accompanied with falling groundwater table, and the resultant water shortage in all sectors [Figs. 1 (a), 1(b)]. The impact of the shortage of rainfall borne droughts would be of the severity scale in the Bangladesh on growing population and development in all sectors of its economy like in urbanization and industrialization, and therefore on demand for more water [11].

2.1 Deforestation and Hydrological Cycle

Vegetation is one of the most important stabilizers of climatic factors- temperature, precipitation and also carbon sequestration. Therefore, deforestation destabilizes climatic factors as it is cutting and clearing of vegetation for fuel, farms, plantations and settlements.

The intensity of deforestation in Bangladesh is increasing with the growing population. For example, in northern Bangladesh, the percentage of vegetation coverage in the densely populated is lower than in the sparsely populated areas.

Deforestation causes the damage of habitat, loss of biodiversity and river bank erosion which brings drought. It can also cause extreme temperatures and low and high precipitation. Literature revealed that average temperature is increasing day by day due to the decreasing vegetation coverage and increasing greenhouse gases.

A greenhouse gases like carbon dioxide are good absorbers of heat radiation. The excess of greenhouse gases in the atmosphere acts as blanket which causes global warming as it traps heat radiation in the atmosphere.

But, deforestation and greenhouse gases are directly related, as deforestation means increased greenhouse gases build-up in the atmosphere due to the diminishing vegetation which harvests them from the atmosphere. Of the 2005 total amount of anthropogenic greenhouse gases (GHGs) emission, 10-12% sourced from farming activities. Reduction N_20 and CH_4 emissions and biomass fuel burning and increased C sequestering are the technical

options applicable in the reduction of greenhouse gases build-up in the atmosphere, and the resultant global warming [44].

Greenhouse gases emission is increasing due to growing industrialization and agricultural practices to meet the demands of growing global populations, and could become a threat of life on the planet if it is left to continue unchecked. If the expansion of agriculture continues to happen through deforestation, it would intensify greenhouse gases build-up in the atmosphere by 10% or approximately 500 Mt $C0_{2\text{-eq}}$ in the period 2015-2020 [45]. Changing patterns of agricultural systems should be considered in the need to mitigate climate change at local and global scales.

The climate change, which is the variability of its variables alter hydrological cycle, with resultant impact on crop production [46] and land degradation [47]. Hydrological that means water cycle is also affected by deforestation. Trees extract groundwater through their roots and release it into the atmosphere through transpiration. Deforestation reduces the content of water in the soil and groundwater as well as atmospheric moisture. Trees help to form cloud and occurring precipitation. Deforestation affects the water cycle significantly as trees roots create macro pores–large channels–in the soil that increase infiltration of water. Vegetation contributes to evaporation and reduces soil moisture via transpiration. Trees litter and other organic residue change soil properties that affect the capacity of soil to store water and litter stems. At last deforestation can cause increase of temperature, loss of soil properties and water holding capacity, and destruction of beneficial organisms of soil.

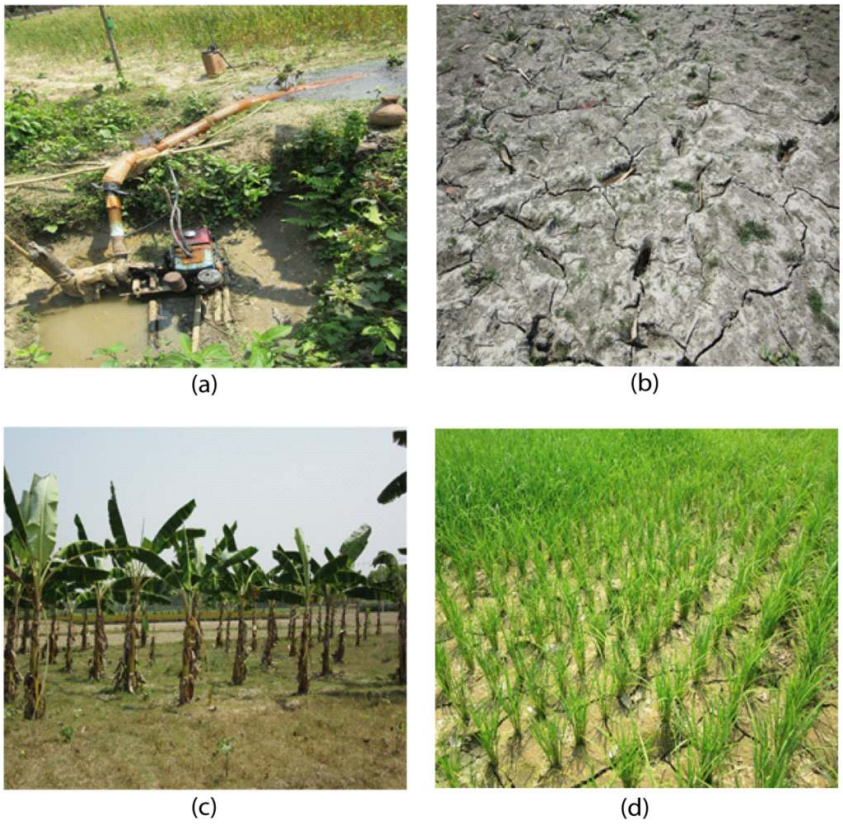

Fig. 1. Illustrations of some severe impacts of drought: a. deepening shallow tube-well water [STW] extraction system for the irrigation purpose. However, it is reflected that water table is gradually falling as the over extraction of groundwater for the irrigation purpose in summer seasons goes on; b. agricultural land dried up, owing to long term rainfall uncertainty; c. agricultural crops [banana] on distress due to water shortage and scorching hot; d. rice field fractured due to water shortage

(Source: Authors' composition)

2.2 Temperature and Agricultural Activities

Extreme temperature impacts adversely on crops and soil characteristics. High temperature is also a key factor in the evolution of new pests and/or decreasing of croplands. The evolution of new kinds of bacteria, algae and virus borne diseases would increase as a result. Crop production would also decrease, inflicting economic losses in the affected regions and whole of the country. The global temperature increase by 2℃ (low-end) predictions by 2100 would impact rural poverty and urban food insecurity [48]. Climatic impacts adversely affect food production, patterns of crop productivity, fishery and livestock system, food distribution and market access [49, 50]. They impair of crop physiological structure along with quality in most of developing countries located on the tropical [51].

Soil quality is also affected by the increasing temperature. Some researchers have suggested that the rising global temperature could be reversed via the control of some important factors like lifestyles and miscellany crop yields, soil and water resource management and plant protection initiatives to obtain controlled crop production [52,53].

Soil temperature is a one of the most important factors in crop production. When soil temperature goes up beyond favorable limits, crops production would be hampered by the effect of temperature borne diseases. The organisms in soil which are beneficial in crops production won't survive in high temperatures. Frogs are one of the most important organisms which are beneficial in crop production. Frogs decrease harmful pests and insects on crops by eating them. But, they won't withstand elevated temperatures. On the hand, farmers apply different chemical pesticides and fertilizers on the crop farms affected by climate change. This application of chemical pesticides and fertilizers kills the beneficial organisms on farms and pollutes ground water. Sometimes water borne diseases may affect in the cropland due to water pollution. In response to the impact of climate change on crop production and growing period, farmers could change crop varieties, crop densities, fertilization levels and sowing dates when planting crops [54].

2.3 Precipitation and Apparent Impact

We often think about drought in relation to the impact of precipitation on the degree of dryness and duration of its period. It is known as a meteorological drought which is highly specific to a region and dependent on the average precipitation which may vary considerably spatially. Low precipitation affects stream flow, soil moisture, reservoirs and lakes water levels, and ground water recharge. Nevertheless, low precipitation always impacted drought severity in the northern part of Bangladesh. Most of the natural hazards and disasters are also of global context owing to global warming, and number of climatic models have projected that, normal precipitation rate decreases in dry season and increases during monsoons in south Asia [55]. Unfavorable conditions of cloud formation could evolve from climate change and cause drought over the country when they persist long. Absence of precipitation in a region causes rise of temperature in the atmosphere [56]. As a result, the soil moisture will decrease slowly due rising evaporation and transpiration by plants. Ground water level also decreases with diminishing precipitation and infiltration of surface water. Agriculture productivity is directly related with soil properties, but has been falling sometimes due to the long term dryness condition of soil components.

Farmers should be aware of the causes of drought and other hazards behind the decrease of ground on water harvesting, water supply programs, excavation and awareness building programs.

In the Northern areas of Bangladesh, depth of water in rivers, ponds, canals, channels is decreasing by continuing river bank erosion and siltation process.

Approximately 80% rainfall is naturally received during the monsoons but river flows are not yet managed to be sustainable. Effective conservation of water for future needs is yet to be achieved [43]. Most of people are blaming hardships and un-successes on the famine and drought prone areas they were settled on. They are not yet started to change their destiny through the mitigation of and/or adaptation to the conditions adversely affecting their living endeavors via the application knowledge and technical solutions.

2.4 Water Crisis and Agricultural Activities

The northern part of Bangladesh is known as a major source of national food production. Most of

the people in this area directly depend on agriculture. Landless labor and farmers depend on the rain-fed agriculture which is now suffering from rainfall and seasonal variability [48]. In the past, the main crops cultivated in the northern parts of Bangladesh were aman and boro rice. Now-a-days, farmers are encouraged to cultivate new varieties of high yielding crops but not yet well informed of the modern agro-technology and cultivation systems they go with [2]. Generally, the overall agricultural productivity in the Northern region is very low mainly due to unavailability of irrigation facilities, inadequate rainfall and less water flow in the rivers.

Drought events and their impacts are more severe than flood damage in Bangladesh [11]. Drought hazards caused more rice production losses than what flooding impacted on aggregate production between 1969-1970 and 1983-1984 respectively [39]. Farmers in the north cultivate aush rice cultivates 2 months late, in August-September instead of June-July. As a result, the physiological structure of the crops is damaged because the rains end at development stage of crop.

Farmers extract more ground water through deep and shallow tube-well for the purposes of agricultural and domestic usage. The amount of ground water extraction increases with the increasing number of deep and shallow tube wells. Ground water level decreases day by day as extraction exceeds the infiltration water into the ground and aquifers [57].

Use of groundwater in households and irrigation is increasing when the decreasing and uncertain monsoon rainfall which is the main source of groundwater recharge is no longer revitalizing groundwater level. Due to the continuing over-extraction of groundwater for irrigation purposes, groundwaters have been depleted in different regions of Bangladesh. The Ministry of Environment and forest of Bangladesh (MOEF) has reported that, aquifer levels have fallen from 8.95 to 18.5 m in some areas of the north-western part of Bangladesh [58]. Table 1 show some historical data on the drought hazards and agricultural and social crisis experienced in different regions of Bangladesh. Long term dryness condition of agricultural soil may accelerate the damaging of soil functions.

Overall productivity in some agricultural crops has decreased due to undesired change of natural climate which tends to inflict drought on crops like wheat, jute, corn, sugarcane, potatoes, several types of pulse and oil seed and, vegetables [59]. Farmers cultivate their crops through inappropriate cropping patterns and changing patterns of land use. Application of chemical fertilizer on farms is increasing and hampering soil quality and water holding capacity. But, productivity in agriculture could be augmented with the application of irrigation and precipitation during the crop growth, in which precipitation is more important than temperature for crop growth.

Table 1. Historical data of drought hazard in Bangladesh

Description of casualties	Affected area	Year
Crop suffered greatly in most cases	Dhaka, Bogra and Sundarbans	1865, 1866, 1872, 1874
Substantially reduced rice production	Severe drought in north-west Bangladesh	1951
Resulted 1974 famine	Northern Bangladesh	1973
Affected more than 50% of the population	47% area of the country	1975
Reduced rice production by about 2 million tons, directly, affected about 42% of the cultivated land and 44% of the population	Wide spread	1978, 1979
Severe drought adversely affected crop production		1981
Drought caused a loss of rice production of about 53,000 t		1982
Drought dried up most of the rivers	Naogaon, Nawabganj, Nilpahamari and Thakurgaon	1989
Immense crop damage, specially to rice, jute and bamboo clumps		1994, 1995, 1996

Source: CEGIS Report [71,4] _ (Modified from Banglapedia, 2006)

Soil water holding capacity could be enhanced to reduce the impact of drought and advance crop yields [60]. Due to the effects of climate change, water availability is already becoming a global issue when overall precipitation is already on gradual decrease in some regions of the world. Along with the uncertainties of climatic variables and their effects on socio-economic environmental effects, climate change calls for efficient use of the limited water available and the development of new water resources [61]. A water system which draws from snow melt or aggregation is more vulnerable to climate change [62].

2.5 Drought Hazards and Social Crisis

Droughts inflict social impacts like life style, health, recreational, social programs and scarcity of water borne social conflicts. Health problems experienced during and after drought are different. There are factors such as poor infrastructure, inadequate financial resources, poor institutional capacity, high incidence of poverty and social inequity, high population density, high spatial and temporal climatic variability and extreme weather events which make Bangladesh more vulnerable to disasters [63]. Statistics have shown that most vulnerable districts in northern Bangladesh are Kishorganj, Badarganj and Kurigram. The health problems experienced during and after droughts include malaria, cholera, dysentery, fever, typhoid, and most important diseases diarrhea [64]. Drought is also a public safety concern as it is a favorable condition for the eruption of fire and health problems. Climate shocks (e.g. drought, heat wave and flooding) lead to losses of life through the impairment of health, loss of properties, and changing of livelihood pattern accompanied with productivity loss and infrastructure destruction [65,66]. Different social activities like marriage and birthday party functions, festival ceremonies and cultural functions are also affected by drought. A family which has lost property due to drought won't be able to mobilize for marriage and other functions easily and/or accordingly. Droughts may change the patterns of cultural functions. People also suffer from anxiety or depression drought borne economic losses.

Climate change and its driving forces lead to acute food insecurity among the populations who spend most of their income on food. Some people in affected areas are often forced to sell household belongings to mobilize for food buying [67]. Using climate based food production technology would help to make balance in the market approaches between food producers and consumers [68]. FAO reported that the number of people identified suffering from chronic hunger from under 800 million (1996) to over a billion were mostly in the hungry countries of south Asia and sub-Saharan Africa [69].

Water shortage could become a common and fundamental crisis in the communities of developing countries. In the northwestern part of Bangladesh, social conflicts are already evolving from water shortages during the dry season [70]. The Government and non-government organization have reduction drought risks via the creation of employment opportunities, financial aids, free food supply, provision of medicines, issuance of relief goods and cloths [4].

3. DROUGHT MITIGATION APPROACH

The Asian region experiences frequent losses of rice production from about 23 million hectares owing to drought [72]. To achieve global Food security to the whole population is one of main challenges in the 21st with a population which is augmenting, but one which is threatened by climate change and stressed environment [73]. Some people are victims of long term anomalies of drought intensity, magnitude and frequency. Drought hazards coping mechanism differ from local (e.g. local people try to cope with drought hazards using indigenous technique) to nationally and internationally [4]. There is a need to continue investing more and more on research and development of solutions for the mitigation of climatic impacts on the productivity of wheat, maize and rice farms [74-80], forests [81], industries [82], water resources in catchment areas [83-86] and landscape [87,88] and/or adaptation where it is the most appropriate. People are already trying adaption to drought hazards via agricultural and non-agricultural mitigation approaches [4]. Agricultural approach denoted some potential aspects of the crop production and agricultural adjustments like the increasing of crop yield, application of irrigation water, re-sowing of crops and compensation for crop loss [28]. Climate variables and even high agricultural technology are considered to be potential factors through which crop productivity could be influenced year to year [54]. In addition, Crop breeding is a substantial way to overcome climatic effects on crop productivity through the increasing of food production [89]. Mitigation of climatic effects on agricultural sectors is arguable [90]. However, biotechnology and conventional

crop breeding are one of the most important approaches through which increase of crop yields could be achieved [91]. Consequently, these two approaches have been developing in consideration of climate change and the need to adapt farming systems in the conditions of drought, heat, pest persistence and waterlog [48].

Sustainable mitigation measure may ensure sustainability in the agricultural sector through the taking of mash networking initiatives. It is the best approach right from the beginning of problem up to the taking of ultimate action to mitigate. Whereas, each and every step of MAR drought mitigation approach (MAR©DMA) would be able to guide for the next step, with which process is suitable for the forthcoming step? However, MAR©DMA is a composite process which consists several steps such as soil management, crop management, tree plantation, reservoir renovation and new reservoir development, rain water harvesting, local reservoir management, river basin management and groundwater management to follow in a consecutive way so as to obtain the reduction of climatic stress (Fig. 2). Each of the steps contains specific point of interest which may indicate to its importance in combating of desertification from a specific site.

Soil management dwells on several aspects its characteristics such as heat protective organic biomass production, texture analysis and mix up with clay, water holding capacity buildup and earth worm culture whereas its standard feature might be to fulfill the agricultural demand at the optimum productivity.

Crop management is one of the vital aspects in the fight against global warming and its adverse environmental impact on crops through the introduction of short duration and high yield crop varieties, evaporation control by genetic engineering and seedling age (e.g. advance). In addition, tree plantation could be helpful to reduce greenhouse gases, and making shadow surroundings of agricultural lands helps to enhance soil properties via soil moisture increasing and water holding capacity buildup from biomass produce.

Rain water harvesting which is properly managed would be a suitable approach and includes local reservoir management, river basin management, and development of new reservoirs at sufficient distance intervals to ensure no unwanted waste water is discharging from local water bodies into groundwater discharge and reduce the degree of agricultural hazards.

Bangladesh is one of the most important agro-economic based countries. Agriculture is the foundation of its socioeconomic aspect. Agricultural productivities which follow upward trends are prerequisites in the fight against food scarcity in the northern part of Bangladesh.

The above drought mitigation approach enables to achieve a sustainable agricultural system through the shearing drought mitigation strategy and social development.

4. SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT

Agricultural livelihood system is already vulnerable and experiencing food insecurity, crop production failures, loss of livestock, lack of appropriate planting materials and seeds, new pattern of pest and diseases [92]. Drought is one of the principal cause famine, death and mass migration and its acts as a limiting factor in the struggles to achieve sustainability in the socioeconomic development of region or countries. In the struggles to achieve sustainable living, peoples are trying to adjust with the changing environment through the application of indigenous knowledge and practices [4].

Sustainability is a key parameter of in the measure of development in society. Sustainable development achieves from the collective influence of different factors in its adaptation to its environment or situational circumstances. A number of these factors have been identified as the most influencing. At the beginning it might be to develop the linkage of development factors through which a sustainable socioeconomic structure could be obtained. In the aspects of strategy development against climatic hazards, sustainable society leads to the ensuring of demand basis in terms of the three most important factors: sustainable agriculture, sustainable water management and sustainable land use (Fig. 3). Each of the factors dwells on sub-categorical factors which would be triggered to deliver development trends which lead to sustainability.

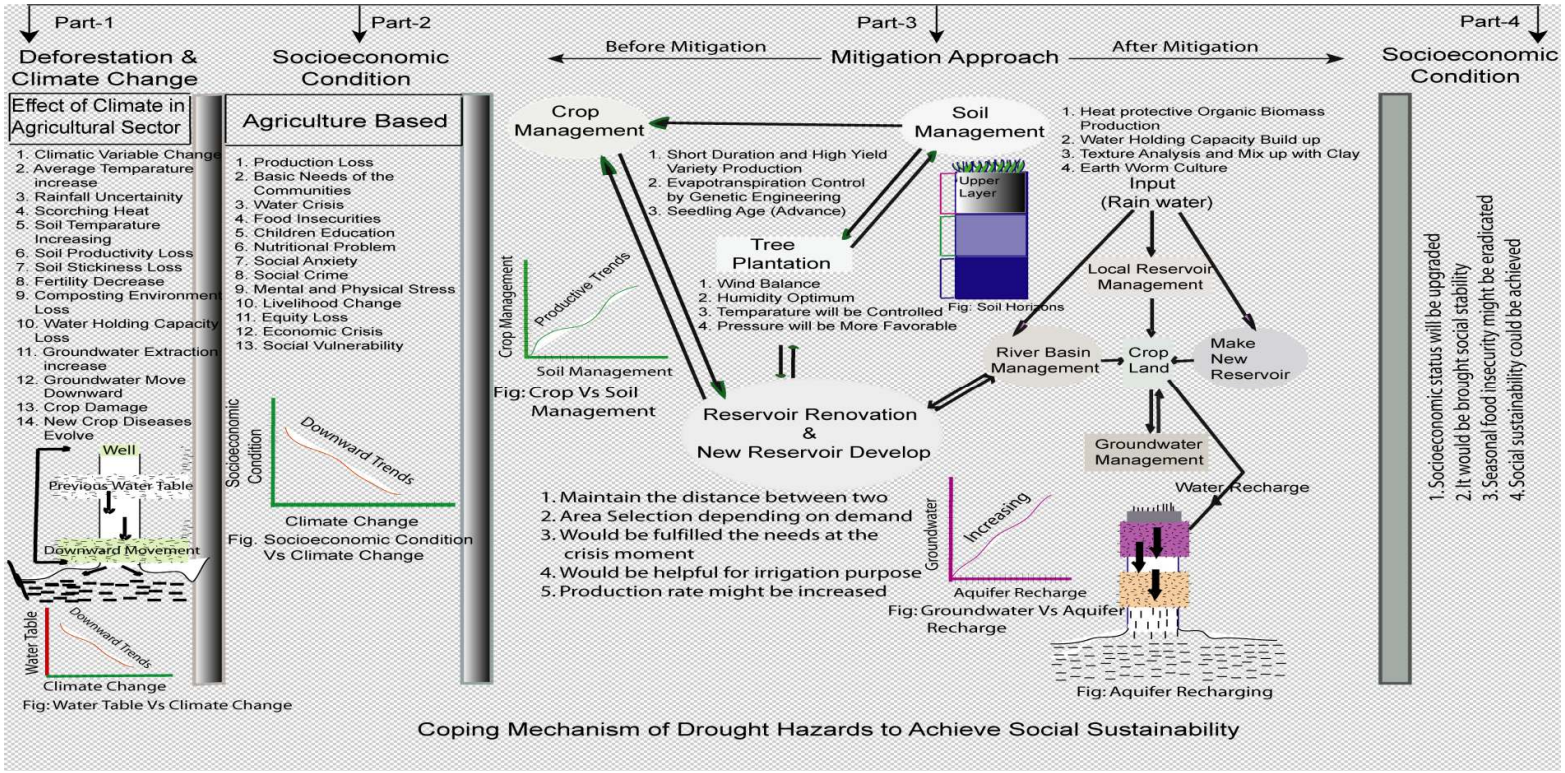

Fig. 2. Shows local scale application of prospective mitigation (MAR©DMA) against drought hazards in the agricultural sector. It has been divided into four parts: 1, 2, 3 and 4 indicated as deforestation & climate change, socioeconomic condition (before mitigation), mitigation approach and socioeconomic condition (after mitigation) respectively. This coping technique tried to accumulate cause and probable solutions to the problems drought impact on agriculture. What are the main climatic effects in agricultural sector? What are the agricultural based socioeconomic crises? What could be the mitigation measures? What would be the possible outcomes after the mitigation measures? In the aspects of mitigation approach, soil management, crop management and water management are considered to be important elements in the ensuring of sustainability in agricultural sectors. Sustainable agricultural practices may accelerate the socioeconomic development trends among local communities

(Source: Authors' Composition)

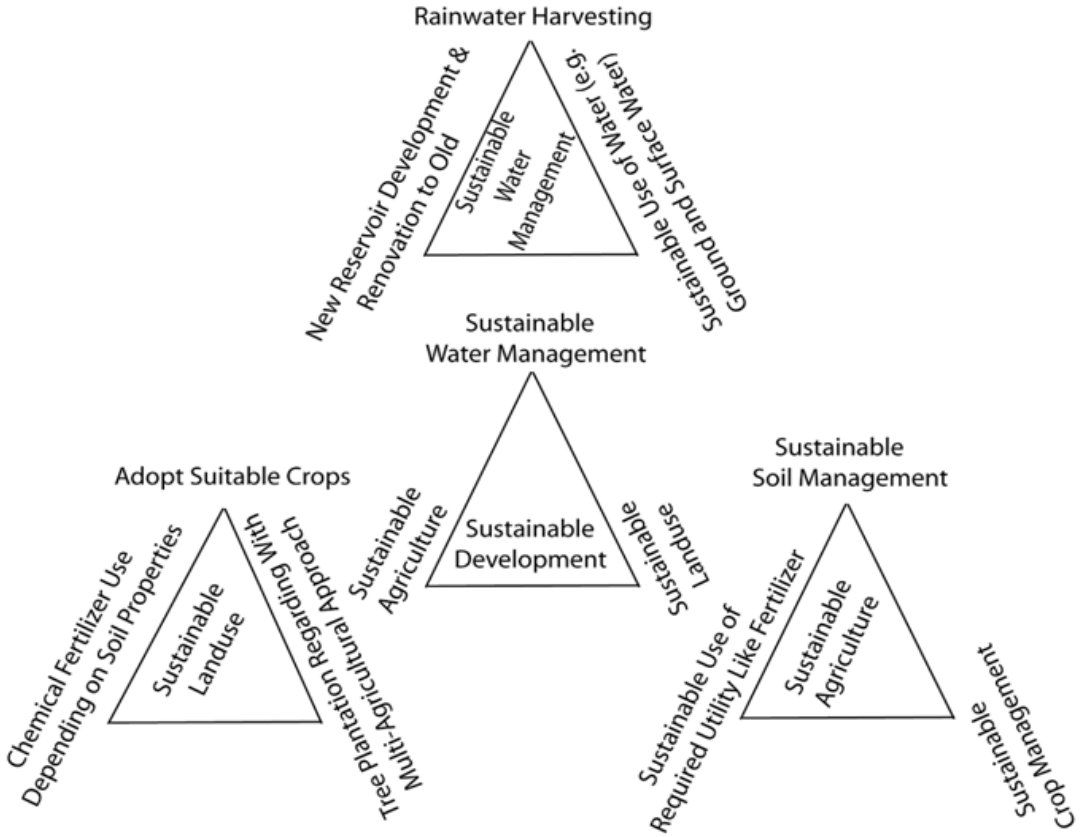

Fig. 3. Illustrates sustainable development approach in the ensuring of sustainability in agricultural components such as water management, land use and agriculture. Each of the key points is embodied with a number of strategic factors that have drawn some crucial facts to deal with in the social security and achieve sustainability in the community

(Source: Authors' composition)

Firstly, sustainable agriculture is embodied with different three factors such as sustainable crop management, sustainable soil management, sustainable utilities of required fertilizer and conditioner. *Secondly*, sustainable land use indicates to another three important factors such as the of adjusting of suitable crops depending on time and place, tree plantation depending on multi-agricultural approach and chemical fertilizer use depending on soil properties and characteristics. *Thirdly*, sustainable water management refers to the three crucial aspects of the probable factors such as new reservoir development and old renovation, rain water harvesting and sustainable use of water (e.g. ground and surface water).

5. CONCLUSION

Drought hazards are ultimate consequences of climate change which has been evolving through unevenly changes of climatic variables. Its pervasiveness's such as intensity and magnitude are not same. The severity of the climatic hazards is dependent on direct and indirect factors that are always inducing change and augmenting negative derivatives of climate change. Its discontinuation and anomalous changing pattern indicate to long term instability of the climatic controlling variables such as temperature. It might be brought to global change whereas the anthropogenic input always adding into the atmosphere would be enough to induce devastating disasters. In Bangladesh, drought is frequently experienced at regional scale or extensively depending on cause and time. And, the main agriculture founded component of the national economy is already on downward trends due to continuous losses in agriculture productivity. Simultaneously, water and land use patterns have been identified as vulnerable components in the gearing up of

social status with enhanced socioeconomic growth which is already on backward trends. So, the negative consequences tend to expedite temperature and rainfall uncertainty, agricultural damage, worsen socioeconomic condition, social and food insecurity. To make balance among the social components it is very important to take some initiative at the national and international levels for accelerating the existing ways of development. On the observational status, it is possible to make some efforts in the mitigation purpose at local scale and obtain balance of agriculture productivity and local agricultural demands. The combined approach includes maintenance of water and land use management for achieving sustainability in the agricultural sector and overall socioeconomic development. It is also important to fulfill the sub-categorical aspects of the three key elements fit on the drought mitigation model to achieve sustainable development. All measures which are mitigations of drought events for sustainability in the agricultural sector should be given consideration.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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